/N-43
21774

Submission to Earth Observation Magazine

Overview of the Landsat-7 Mission

Darrel Williams and James Irons
Landsat Project Science Office
NASA Goddard Space Flight Center
and
Samuel N. Goward and Jeffery Masek
Landsat Science Team
Geography, University of Maryland College Park

Landsat-7 is scheduled for launch on April 15 from the Western Test Range at Vandenberg Air Force Base, Calif., on a Delta-II expendable launch vehicle. The Landsat 7 satellite consists of a spacecraft bus being provided by Lockheed Martin Missiles and Space (Valley Forge, Pa.) and the Enhanced Thematic Mapper Plus instrument built by Raytheon (formerly Hughes) Santa Barbara Remote Sensing (Santa Barbara, Calif.).

The instrument on board Landsat 7 is the Enhanced Thematic Mapper Plus (ETM+). ETM+ improves upon the previous Thematic Mapper (TM) instruments on Landsat's 4 and 5 (Fig. 1a and 1b). It includes the previous 7 spectral bands measuring reflected solar radiation and emitted thermal emissions but, in addition, includes a new 15 m panchromatic (visible-near infrared) band. The spatial resolution of the thermal infrared band has also been improved to 60 m. Both the radiometric precision and accuracy of the sensor are also improved from the previous TM sensors.

After being launched into a sun-synchronous polar orbit, the satellite will use on-board propulsion to adjust its orbit to a circular altitude of 438 miles (705 kilometers) crossing the equator at approximately 10 a.m. on its southward track. This orbit will place Landsat 7 along the same ground track as previous Landsat satellites. The orbit will be maintained with periodic adjustments for the life of the mission. A three-axis attitude control subsystem will stabilize the satellite and keep the instrument pointed toward the Earth to within 0.05 degrees. Later this year, plans call for the NASA Earth Observation System (EOS) Terra (AM-1) observatory and the experimental EO-1 mission to closely follow Landsat-7's orbit to support synergistic research and applications from this new suite of terrestrial sensor systems.

Landsat is the United States' oldest land-surface observation satellite system, with satellites continuously operating since 1972. Although the program has scored numerous successes in scientific and resource-management applications, Landsat has had a tumultuous history of management and funding changes over its nearly 27-year history. Landsat-7 marks a new direction in the program to reduce the cost of data and increase systematic global coverage for use in global change research as well as commercial and regional applications. With the passage of the Land Remote Sensing Policy Act in 1992, oversight of the Landsat program began to shift from the commercial sector to the federal government. NASA integrated Landsat-7 into its EOS science program in 1994. Landsat-7 is managed and operated jointly by NASA and U.S. Geological Survey (USGS). As a result, the costs of acquiring observations from

Landsat-7 will decrease significantly from that experienced with Landsat's 4 and 5. During the first 12 to 15 months of operation, the cost of a single Landsat-7 scene from the USGS Earth Resources Observation Center (EROS) archive will be $475.00 for raw data (Level 0R) and ~$600.00 for radiometrically and/or geometrically processed observations (Level 1R or Level 1G).

The launch of Landsat-7 will initiate a new era in land remote sensing. The mission operations, for the first time, are designed to accumulate annually, a global, seasonally refreshed, essentially cloud-free, US-held archive of observations. The EROS Data Center, in Sioux Falls, South Dakota will be the repository for this US archive. The US global archive is capable of accepting 250 scenes/day (>90,000 scenes per year). Acquisitions for the US archive will be accumulated by an automated Long Term Acquisition Plan (LTAP). The NASA Landsat Project Science Office, at the Goddard Space Flight Center, developed this plan in cooperation with members of the NASA Landsat Science Team. The LTAP attempts to optimize the quality of acquisitions through consideration of land seasonal dynamics and forecasted cloud conditions. Landsat 7 operations are configured to acquire all scenes in the United States, including Alaska and Hawaii. For other regions of the globe observations are concentrated in vegetation growing seasons with reduced acquisitions during dormant periods and for major deserts and ice sheets. Once every 24 hours cloud cover forecasts are acquired from the National Oceanic and Atmospheric Administration. These forecasts are compared to local cloud cover climatology to determine next day acquisition priorities from among all the scenes specified for possible acquisition that day, which is, on average, about 400 scenes. Pre-launch tests of the LTAP produced complete global coverage within one year and resulted in reduced cloud contamination (Fig. 2). In addition to the US acquisitions, as many as 18-20 international ground stations (IGS') are expected to sign agreements with NASA and USGS to receive direct broadcast of observations for their acquisition regions. Given the implementation of the LTAP, the need for considering special requests for specific scene acquisitions is minimized -- basically, if an area is highly likely to be cloud-free, it will probably be scheduled for acquisition. Also, most of the IGS' will be collecting full coverage within their acquisition range. While the imagery collected by the IGS' will be held locally, metadata are to be provided routinely to the EROS Data Center, allowing users to search the foreign archives. This combination of systematic US global acquisitions and high volume international collections will provide a rich new source of earth information for scientific research and applications[1].

There is no question that the newly revitalized Landsat mission, with the deployment of Landsat-7, will serve as a major stimulus for science discoveries and successful applications in environmental and resource management. Throughout the mission's history the diversity of applications developed for Landsat make it unique among Earth observation satellites. Images acquired by Landsat satellites were used to produce the first composite multi-spectral mosaic of the 48 contiguous United States. They have

[1] Annually, the US archive at the EROS Data Center is expected to accumulate over 90,000 scenes. In total, including the IGS operations, over 193,000 scenes should be collected each year. In any given year there are approximately 310,000 land scenes possible. Thus Landsat-7 will acquire better than 60% of all possible scenes, which, when considering cloud cover, is about the number of good scenes available for Landsat to acquire.

been used to monitor deforestation, map the extent of winter snow pack, and measure forest cover at the state level. In addition, Landsat has been used to locate mineral deposits, monitor strip mining and mining reclamation, and to assess natural changes due to fires and insect infestations.

With the substantial cost reduction and systematic acquisition strategy, Landsat observations will, once again, become the foundation for both terrestrial research and applications activities. Landsat fills a critical niche among NASA's earth observatories because it 's combination of high spatial resolution (30 m nominal), high quality radiometric and spectral discrimination, and 16 day repeat cycle provides a unique perspective to assess land cover dynamics at the scale where human activities are clearly evident. This information is of critical importance for global change researchers since many of the Earth system changes originate from human activities and many of the anticipated changes will be most significant to local human communities.

For regional and local applications of remote sensing and GIS technology, Landsat observations also provide the regional (and seasonal) context within which to understand the local patterns revealed in both traditional and newly developed high spatial resolution sensors and related geographic information. Many new sources of high spatial resolution observations will shortly be available, including the 1-4 m images supplied by Space Imaging Corp. from their IKONOS sensor, as well as aircraft measurements being acquired with new electronic systems such as the Positive Systems electronic camera and the Intermap active radar system. A combination of these high spatial resolution observations with Landsat realizes the dream of remote sensing scientists to accomplish detailed local assessments within the context of regional conditions. This multi-scale, geographic analysis approach is known to produce highly relevant and valuable information about local conditions. However, to date it had been exceptionally difficult to access the needed data in a timely and cost-efficient manner. The combination of systematic Landsat observations and commercially–available high-resolution imagery realizes this dream.

An intriguing aspect of the new Landsat-7 program, for both the science and commercial applications communities, are the new opportunities and challenges presented by this mission. The unique attributes of the Landsat-7 mission include not just the improved sensor capabilities but, more importantly, the high volume availability of systematic, multi-temporal global observations. Experience over the last quarter century with Landsat has demonstrated consistently that land feature discrimination is substantially enhanced with multi-temporal observations. The design and development of analytical systems that capture this potential are now waiting to be innovated. Serious problems previously encountered in cloud cover contamination for some regions of the globe may now be addressed with image compositing, a method not frequently applied to Landsat observations. With low-cost observations it is now feasible to conduct large region studies with 100's – 1000's of scenes, rather than limiting applications to a few spot assessments. However, to do so will require new approaches to handling, processing and analysis of the data, as well as reporting the results. These demands push the frontiers of both computer technology and scientific understanding. Indeed the new Landsat-7 mission is pushing the boundaries of science and technology applications in earth science today as much as the original NASA Earth

Resources Technology Satellite (Landsat-1) pushed the frontiers of our understanding a quarter century ago.

NASA recognizes that moderate resolution, multispectral observations, like those from Landsat-7, will continue to be an important part of terrestrial monitoring. Currently, a variety of options are being considered for the provision of these data to the user community. The Earth Observing –1 (EO-1) mission, part of NASA's New Millennium Program, offers a glimpse at some of the advanced technologies that may be a part of the post-Landsat-7 era. Scheduled to launch in December, 1999, EO-1 will carry aboard an Advanced Land Imager (ALI) pushbroom VNIR-SWIR multispectral sensor, the Hyperion hyperspectral sensor, and a new instrument designed to collect the data necessary for performing atmospheric corrections to the ALI imagery. These technologies offer improved performance, as well as considerable savings in total weight and cost.

Figure Captions:

Figs. 1a and 1b: (a) Landsat-5 Thematic Mapper image of Washington D.C. acquired in October, 1996. Like Landsat TM, ETM+ data will be characterized by fine (15-30 m) spatial resolution and complete multispectral coverage throughout the visible, near-, mid-, and thermal infrared. (b) Landsat-5 TM image of the Mt. St. Helens area in Oregon acquired in May, 1992. Here the TM data have been "draped" over a digital elevation model to render a three-dimensional view of how the mountain looks several years after the volcanic eruption. The vertical relief has been exaggerated by a factor of 2x. Using this technique, "fly by's" of entire regions can be created. Such products are used in flight simulation training.

Fig. 2: Simulated acquisition pattern for one year of Landsat-7 operations, using Long-term Acquisition Plan (LTAP). The LTAP takes into account cloud-cover, seasonal vegetation patterns, and instrument gain changes to maximize acquisitions that characterize landcover changes around the globe. Dark red regions (including the United States) are acquired on every overpass (22 acquisitions/year), while yellow areas are acquired at least once each year.

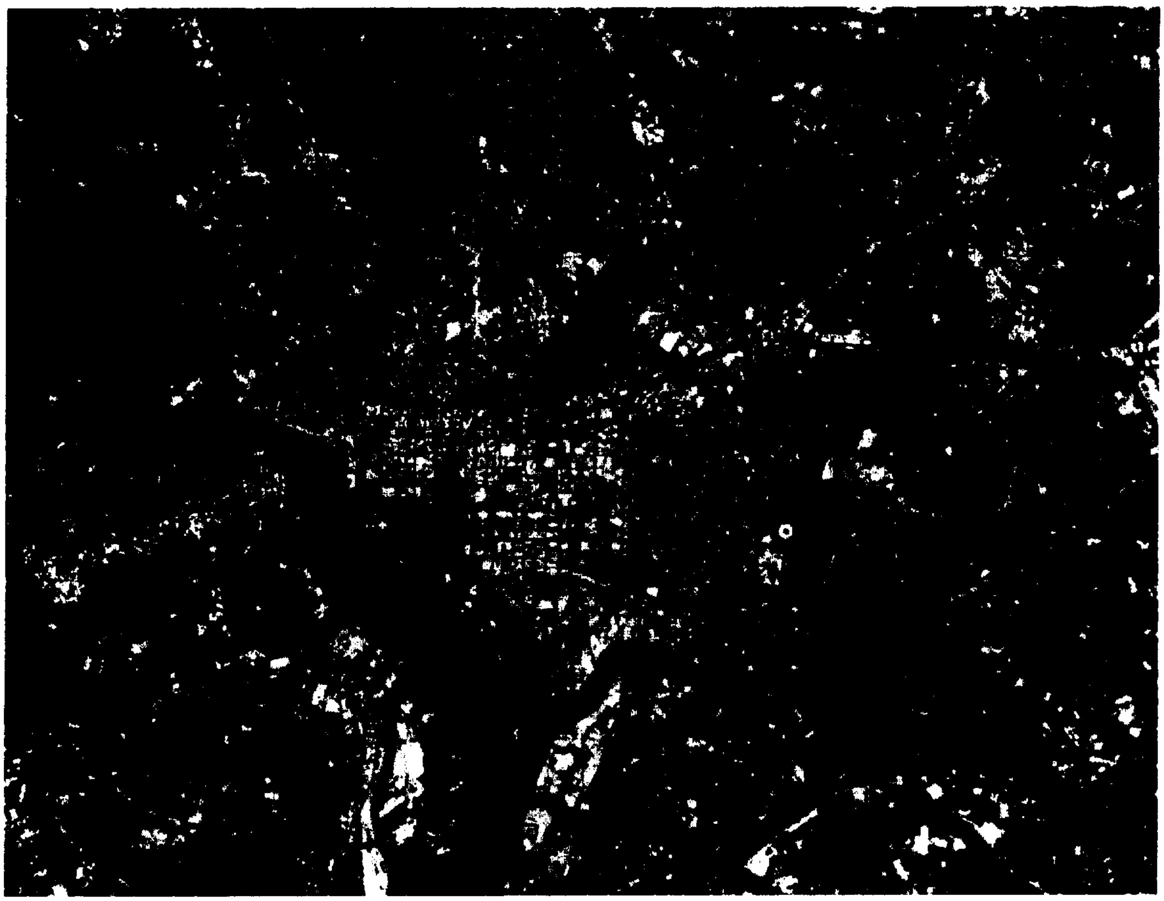

Fig 1a

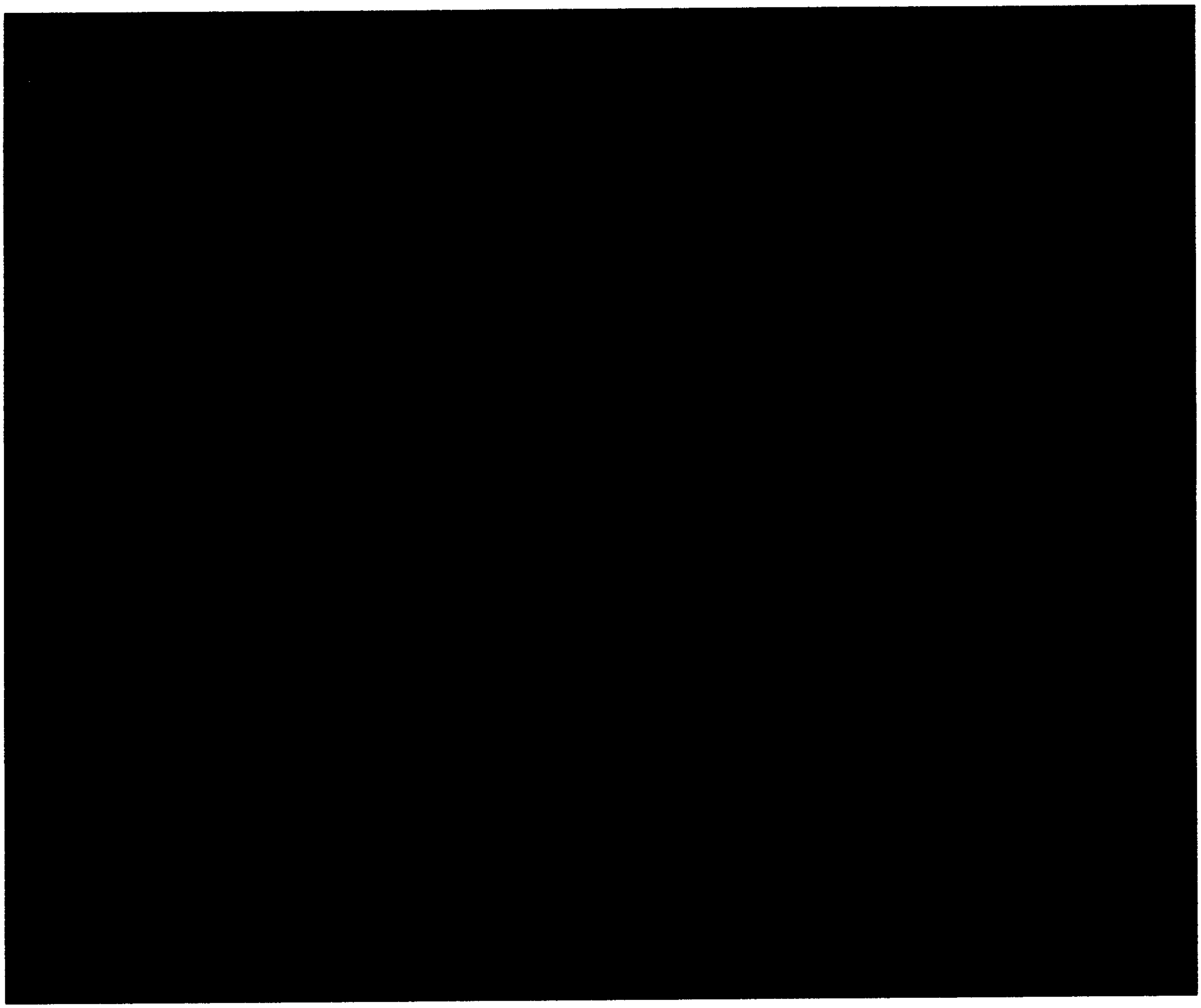

Fig 1b

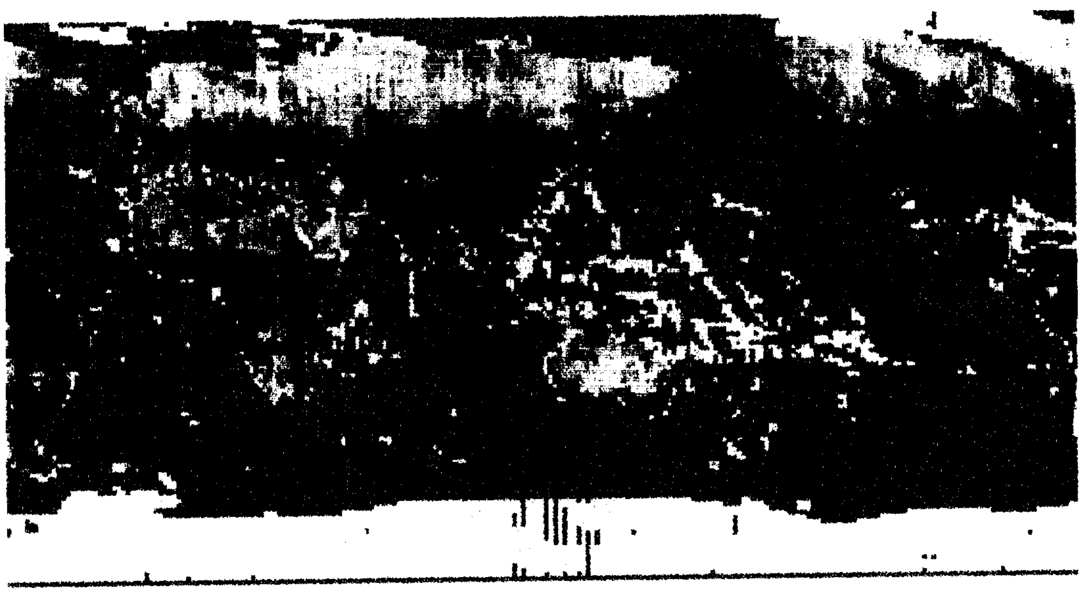

Fig 2